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13. ABSTRACT *(Maximum 200 words)*
This DURIP grant, with $96k from DOD and S32k of the University of Kansas matching fund, has been utilized to construct a high-vacuum thin film evaporation chamber. Construction of the major part of the chamber was completed before the expiration of the grant. Installation of the second e-gun was completed at the end of 2001. Installation of the R±IEEDsystem will be completed by the first quarter of 2003 due to late delivery of the hardware. A picture of the chamber is shown in Fig. 1. Several research projects have been initiated recently after the chamber was tested. This allows the Pt to extend her research on high-temperature superconducting thin films, particularly Hg-HTS thin films, to coated conductors, which has been considered a critical enabling technology for high power microwave sources in future Air Force systems. The goal to leverage the expertise developed in P1's laboratory in epitaxy of Hg-HTS thin films and apply it to coated conductor applications has been met. The details of the research enabled by this chamber are described in the following. Several manuscripts are under development based on the recent results obtained from this chamber.

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Construction of Vacuum Deposition System for Research of Hg-based High Temperature Superconductors Coated Conductors

AFOSR Grant/Contract #F49620-01-1-0226
Final Report
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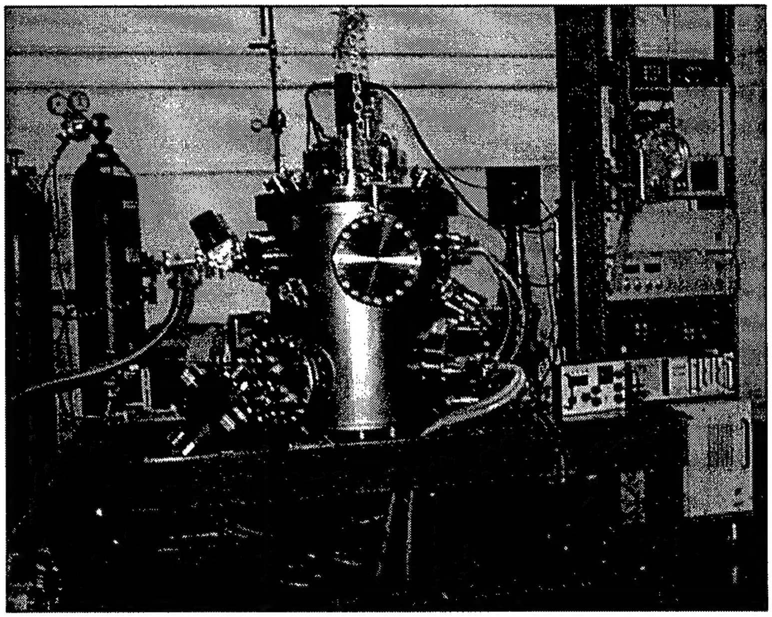
OBJECTIVES

Construct an advanced vacuum deposition system for fabrication of high temperature superconducting (HTS) thin films and buffer layers on oxide and metal substrates.

STATUS OF EFFORT and FOCUS OF FUTURE EFFORTS

This DURIP grant, with $96k from DOD and $32k of the University of Kansas matching fund, has been utilized to construct a high-vacuum thin film evaporation chamber. Construction of the major part of the chamber was completed before the expiration of the grant. Installation of the second e-gun was completed at the end of 2001. Installation of the RHEED system will be completed by the first quarter of 2003 due to late delivery of the hardware. A picture of the chamber is shown in Fig. 1. Several research projects have been initiated recently after the chamber was tested. This allows the PI to extend her research on high-temperature superconducting thin films, particularly Hg-HTS thin films, to coated conductors, which has been considered a critical enabling technology for high power microwave sources in future Air Force systems. The goal to leverage the expertise developed in PI's laboratory in epitaxy of Hg-HTS thin films and apply it to coated conductor applications has been met. The details of the research enabled by this chamber are described in the following. Several manuscripts are under development based on the recent results obtained from this chamber.

Ion beam-assisted e-beam Deposition system



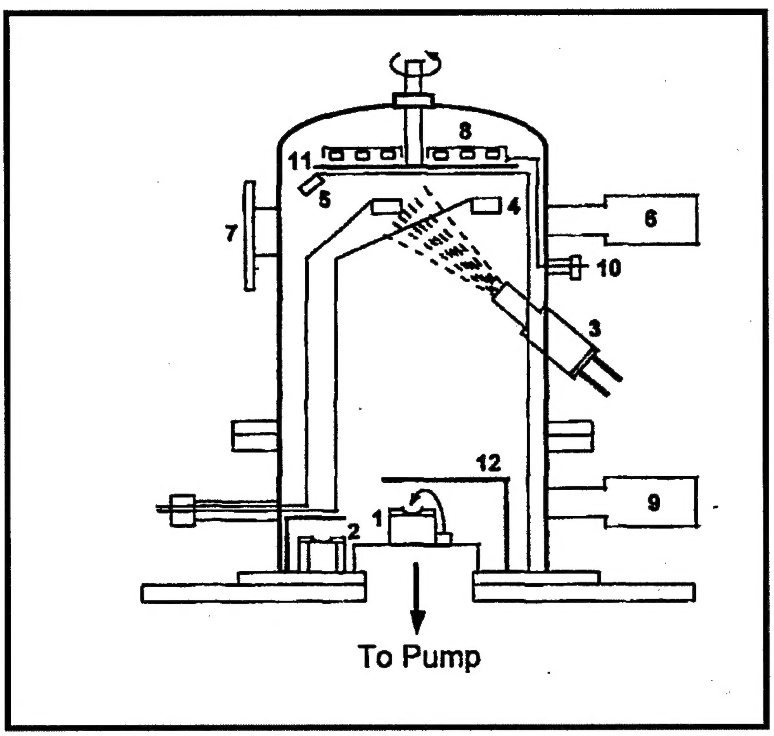


Fig. 1 Pictures (upper) and schematic (lower) of the IBAD e-beam evaporation system constructed under this DURIP fund. In the lower panel, 1—e-gun; 3—ion source; 11—substrate facing down; 6—RHEED gun; and 7—RHEED screen port.

Research Initiated

- **Growth of Textured Templates on Metals**

In studying the epitaxy of high-T_c superconducting coated conductors (HTScc, including YBCO, Tl-based and Hg-based superconductors in our research) we emphasize understanding the growth mechanism of HTS films on "standard" buffer layers including CeO_2, and YSZ as well as on other newly emerged buffers, especially conductive buffers. We have started growth of various textured templates and buffers on metal substrates in this new chamber. Since this new chamber is equipped ion beam that can be used for ion-beam assisted growth (IBAD), growth of different IBAD templates has been the major topic of our group recently. The focus of this study is on the evolution of bi-axial textures during the IBAD process and the effect of the interfacial morphologies on the texture of the template. Both insulating and conductive buffers have been employed for our IBAD growth. The candidates for the former, besides MgO and YSZ as already demonstrated by other groups, include $LaAlO_3$, $SrTiO_3$, CeO_2 and $LaZrO_3$. On the other hand, since a conductive buffer layer is ideal for superconducting tape applications, several conductive oxide buffers, such as Cu, Ni, $SrRuO_3$ and $LaNiO_3$, are also under investigation. The goal is to explore the best architecture for HTS coated conductors. Several topics to be studied include: (1) chemical compatibility of YBCO and Tl-HTS precursor films to various buffers; (2) interface microstructures of YBCO in PLD, and Tl-HTS precursor films grown in FTRA process, and the influence of the processing parameters such as heating rate, processing temperature, and Tl-, and O-vapor partial pressures; (3) microstructural variation of the films during the Tl-Hg cation exchange, especially the film/buffer and buffer/metal-substrate interfaces, and the quality of film epitaxy.

- **Growth of Thick HTS Films for High I_cs,**

Growth of thick films in the range of 1-3 μm in thickness is desirable for high I_c's and high I_c's and has been carried out by investigating changes in film microstructures (quality of epitaxy, film/substrate interface and surface morphology) and electro-magnetic properties (T_c, J_c, H_{irr}, etc.) as functions of film thickness. We have taken two approaches, one is pulsed laser

deposition (PLD) and the other, co-evaporation in this newly completed evaporation chamber. For PLD thick HTS films, YBCO, Tl-2212 and Hg-1212 thick films up to 3 microns in thickness have been obtained. High J_cs above 1MA/cm^2 have been achieved on these films at 77 K and self field. Nevertheless, these J_cs are still much lower than that of thin HTS films. Investigation of the thickness dependence and depth profiles of the J_cs on these thick HTS films is the focus of our current research. On the other hand, the co-evaporation capability in our new chamber may provide an alternative thick film process that differs from most existing processes employed so far due to the oxygen pocket heating (real blackbody heating). Growth of thick YBCO films using this technique is ongoing in our laboratory.

An optimized architecture for coated conductors requires the HTS layer to have a high J_c and a thickness in the range of 1-5 μm in order to carry adequate currents (100-100A) and maintain good overall current density (J_e~ 20-40 kA/cm^2 at temperatures near 77K). The reach this goal, the following problems will be studied when the thickness of the films is varied from 0.2 μm to 3 μm: (1) growth time of Tl-HTS (Tl-2212 and Tl-1212) precursor films; (2) influence of Tl-, O-and Ar-vapor partial pressures on the growth rate of Tl-HTS precursor films; (3) growth rate of Hg-HTS films in the cation-exchange process; (4) effect of substrate microstructures (a comparison between single-crystal and buffered metal substrates will be made) on the cation-exchange rate; and (5) influence of oxygen content in the Tl-HTS precursor films on the cation-exchange rate.

Although most samples will be characterized in terms of structure, surface morphology, T_c, and $J_c(T, H)$, the main focus of this project will be $J_c(T, H, d)$ as it relates directly to the power applications. Generally, a high J_c can be maintained in HTS films when their thickness is smaller than a threshold value (d_{th}). It is hence desirable to maximize the d_{th} so that a higher current can be carried in a superconducting tape. To obtain insights into the $J_c(T, H, d)$ behavior, the following topics will be studied: (1) d_{th} on single-crystal and metal substrates and the effect of substrate on d_{th}; (2) correlation between d_{th} and film micro-structural characteristics, especially the quality of epitaxy and the properties of grain boundaries; (3) correlation between the d_{th} and

the processing conditions for Hg-HTS coated conductors; and (4) ways to increase d_{th}, such as introduction of growth defects, etc.

- **Scale-up HTS coated Conductors to Long Lengths**

The issue of scale-up will be addressed via development of batch processing apparatus for Hg-HTScc. Understanding the growth mechanism in the batch processing is the focus of this study and it is anticipated that a prototype of system is developed through this research, which can be transferred to industry for production of tapes in kilometers.

The ultimate requirement for coated conductors is to fabricate tapes in kilometers. Many technical problems have to be solved in order to scale up the process developed for short piece samples to long lengths. Two steps will be taken in scaling-up of the current Hg-HTS's coating process. In Step 1: we will develop an optimized process, based on the FTRA and cation-exchange processes, for coating Hg-HTS's on short-piece conductors. Understanding the growth kinetics of Tl-HTS precursor film in FTRA and Hg-HTS films in cation-exchange process is the key towards this optimization and the goal is to obtain a control of the growth process. A phase diagram will be developed from such a study and used to guide the process scale-up. This optimized process should not only yield high quality Hg-HTScc, but also is robust enough when applied to large-scale tape fabrications. In Step 2: a new apparatus will be designed and assembled, based on the results from Step 1, for batch processing of Hg-HTScc with the tape length extended to ~ 1 meter. Metal substrates, including RABiTs, IBAD, and others available through our collaboration, will be used for this experiment. The new chamber will be used for deposition of HTS as well as buffers on these metal substrates. This effort is to demonstrate that the physical properties achieved on short piece HTScc can be obtained in long pieces (>1 meter) using the batch processing. Although we will not directly produce kilometer-length Hg-HTS tapes in the proposed research period, it is anticipated that the processes developed in the project will be transferred to industry for large-scale Hg-HTS's tape production.